

Derivation of Emission Factors for Nanjing, China Using MOBILE5

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ABSTRACT

The worsened air pollution problem caused by the rapid growth of the urban traffic in China has generated an urgent need to perform the Environmental Impact Assessment, as an integral component of the overall assessment of urban transport planning scenarios. Currently there exist no effective methods in China that can be used to estimate motor vehicles' exhaust emission factors, one of key parameters in performing environmental impact assessment. This paper intends to generate emission factors using MOBILE5 emission factor model that adapt to China's urban transport environment. Emission parameters are collected in Nanjing City, which are used to generate its emission factors at various average speeds. Correction factors to MOBILE5 are proposed for applications to urban transport planning in China.

Keywords: Urban Transport Planning, Motor Vehicle Exhaust, Emission Factor, Environmental Impact Assessment, Nanjing China

INTRODUCTION

The air pollution from road traffic has become an important environmental problem in Chinese cities. In many large cities, the air pollution is continuously worsened because of the increased exhaust emissions from rapidly growing number of motor vehicles (1). In the assessment of urban transport planning scenarios, the assessment of air pollution from road traffic has become an important and integral component. The traditional travel demand forecasting in the urban transportation planning process can produce traffic volumes, average speeds, and average delays of vehicles, which can be compared with the field collected data for the purpose of calibration (2). The air pollution assessment of transport planning scenarios in China requires the computation of the concentrations of CO and NO_x near the roads, and if the concentrations exceed the Chinese National Air Quality Standard (3), some strategies will be needed to reduce the pollution. In this process, the emission factors of CO and NO_x are key parameters input to the dispersion model to compute concentrations and will significantly influence the assessment result.

Wang, etc at Southeast University have assessed the air pollution of CO emitted from motor vehicles in the urban transport planning for Zhenjiang City and Hefei City in China (4). The CO emission factors used and suggested involve considerable errors because they are too old to represent the current road and vehicle conditions. Further, those emission factors are not sensitive to the average speeds and do not include emission factors for NO_x and HC either.

Environmental impact assessment in urban transport planning requires: first, emission factors be given for a variety of vehicle types; second, emission factors be given for diverse range of average vehicle speeds; and third, the idle emission factors of vehicles stopped at intersections be available. However, in China, there exist no emission factors that meet all of the above requirements. Neither do there exist effective methods that can be used to estimate emission factors for urban transport planning purpose. In this context, the research in this paper is intended to collect the necessary data in Nanjing City, which is a metropolis of Jiangsu Province in East China, and generate the emission factors for the city.

REVIEW OF METHODS TO ESTIMATE EMISSION FACTORS

The driving trajectory of a vehicle on urban roads is very complex, which includes a comprehensive mix of driving at cruise, deceleration, idle and acceleration modes between its origin and destination. This driving behavior on the urban roads is described by a concept called driving cycle. The Standard Driving Cycles of China are described in the Nation's Test Procedure for vehicles exhaust emissions (5). Li, etc (6) have carried out on-road experiments in Beijing and Dai, etc (7) in Shanghai on driving cycles, and they concluded that in general the Standard Driving Cycle can well represent the driving cycles of vehicles running on grade roads in Chinese Cities.

In the developed countries, a number of computer-based emission factor models have been developed based on the in-laboratory emission tests. The widely used models include MOBILE by the U.S. Environmental Protection Agency (8), EMFAC by the U.S. California (9) and COPERT by the European Unions (10, 11). The newest version of MOBILE6 is officially released January 29, 2002 (12). And there are other more macroscopic, mesoscopic and microscopic emission models which are not stated here.

Currently the MOBILE model outputs are being used for preparation of regional emission inventories, assessment of air quality impacts of transportation projects, documentation of

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emissions reductions in State Implementation Plans, evaluation of prospective emission reduction measures, conformity determinations, etc. (13). Zietsman and Rilett used MOBILE5a to compute the emission rates, and combined the output of the Transportation Analysis and Simulation System (TRANSIMS) model to analyze the aggregation in vehicular emission estimation (14). They also used MOBILE5a to compute the Equivalency Factors for both the aggregate and disaggregate cases to allocate responsibility for mobile source emissions (15). Herzog, etc. developed a model for estimating air quality and congestion relief benefits of commuter choice program, and the model used a look-up table of emission factors from MOBILE to estimate the resulting emission changes (16). Miller, etc. used draft version of MOBILE6 model to analyze the effect of county level income on vehicle age distribution and emissions in Tennessee (17).

More literatures discussed the input parameters of MOBILE. Granell, etc. used the Georgia motor vehicle registration to discuss locality specific fleet distributions (18). Nair, etc. formulated and implemented a methodology for modeling soak-time durations (19). Qiao, etc. put forward a model for vehicle age distribution with Houston data (20). Everett and Sacs presented an alternative methodology for collecting local vehicle start information for use in MOBILE6 (21).

Now China does not have an emission factor model that has been developed based on the emission tests on its own vehicle and traffic conditions. He and Fu have used MOBILE to generate the emission factors for Beijing (22). Before China develops its own good emission factor models, the use of MOBILE with certain corrections based on Chinese local unique vehicle and traffic scenarios seems unavoidable and may last for a rather long time.

CORRECTION TO PARAMETERS OF MOBILE5

MOBILE5 (8) classifies vehicles into eight types as listed in TABLE 1. The driving cycle of the Federal Test Procedure (FTP-75) is used to test the Basic Emission Rates (BERs) of vehicles. In the FTP test procedure, the BERs are linear to the running mileage. The emission factors are computed by adjusting the BERs according to parameters of average speed, motor vehicle's mileage distribution, vehicle registration distribution, temperature, Inspection and Maintenance (I/M) program and so on.

In China, correcting parameters of MOBILE5 based on Chinese unique vehicle and traffic scenarios is key to successful generation of its accurate emission factors. The following sections are a list of some of important parameters of MOBILE5 that should be corrected based on the Chinese unique vehicle and road situations. The correction method used in this paper for each parameter is also discussed.

Basic Emission Rates

The BERs are the most important input parameter of MOBILE5. The values for Chinese vehicles are probably several times larger than those of U.S.A, so the MOBILE default values cannot be used.

In a project supported by World Bank, Tsinghua University, Beijing Automobile Research Institute, China Academy of Environmental Science, etc conducted the test of emission rates of currently used vehicles (23). The types of the tested vehicles were classified in a more detailed manner than the Chinese National Emission Test Standard (5). A comparison of the tested vehicle types, the vehicle types of MOBILE5, as well as Chinese National Emission Test

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Standard (5) is listed in TABLE 1. Since in China there were very few Light Duty Diesel Vehicles (LDDV) and Light Duty Diesel Trucks (LDDT), they were not considered further. As a result of comparison, the tested passenger car, mini-vehicle, jeep, middle vehicle, Heavy Duty Gasoline Vehicle (HDGV) and motorcycle (MC) corresponded to LDGV, LDGT1, LDGT1, LDGT2, HDGV and MC of MOBILE5 respectively. The tested number of vehicles was 62 passenger cars, 18 mini-vehicles, 15 jeeps, 11 middle vehicles, 13 heavy duty gasoline vehicles, and 52 motorcycles. The number and types of the tested vehicles and other detail can be found in their research report (23).

The vehicles were tested using the Chinese National Standard Driving Cycle (5), which is different from FTP driving cycle. For comparison, some vehicles were tested with FTP-75 driving cycle of MOBILE5. The resulting BERs from these two driving cycles were compared. Then the tested BERs the Chinese Standard Driving Cycle were transferred to the values of FTP cycle, which are listed in TABLE 2. The transferred BERs of FTP are input into MOBILE5. The BERs in China are now close to the values in U.S.A at the end of 1970's.

Annual Mileage Accumulation Rates

The Annual Mileage Accumulation Rates is one of the key parameters of MOBILE5, and is described as the running mileage of currently used motor vehicles by vehicle type and age. There exists a big difference of this parameter between U.S.A and China because of the different driving behaviors. In China, there are much less personal cars and the running mileage is less except for the Taxi.

In this paper, the following sampling method is used to generate the Annual Mileage Accumulation Rates. First, a survey is conducted to collect the age and running mileage of currently used motor vehicles at the parking lots and the Inspecting Station of the Motor Vehicle Management Department in Chinese cities. Proper sampling size should be used in order to represent the situation of all vehicles in the city. Then the vehicle age is taken as independent variable and the running mileage by vehicle type is taken as the dependent variable in conducting the least-square regression analysis. The regression equations can represent the Mileage Accumulation by age and vehicle type. The Logarithm Function is found the best to conduct this regression analysis because in China the Annual Mileage Accumulation Rate decreases with the increase of vehicle age. But in the several years after the new vehicle's registration, the Least-Square Linear Function is better than the Logarithm Function.

Registration Distribution

MOBILE5's emission factor calculations rely in part on the registration distribution by age for each vehicle type. Users may develop registration distribution by age on the basis of locality-specific data. In China, motor vehicles will usually be enforced to expire after 12 years of use according to the Chinese National Regulations on Motor Vehicles' Using-year. So the registration distribution is obviously different from that in U.S.A.

In China, we suggest to compute the registration distribution with the following equation.

$$V_{ij} = \frac{R_{ij}}{\sum_{i=1}^{N_j} R_{ij}} \quad (1)$$

where i is registration year, j is vehicle type, V_{ij} is the vehicle registration distribution value of j th vehicle type at i th registration year, R_{ij} is the number of j th type of new vehicles registered at i th year, and N_j is the expired year of j th type of vehicles. R_{ij} can be obtained from the Motor Vehicle Management Department of Chinese cities. N_j is taken as 12 here according to the Chinese National Regulations.

Inspection and Maintenance Program

Inspection and Maintenance (I/M) program is an important parameter of MOBILE5. However, in China there is still no effective I/M program and the current I/M program is only annual inspection and discontinuous on-road inspection. The test of idle exhaust emission is one obligatory item of the annual inspection. MOBILE5 input for China is as followings: the inspection type is spot inspection, inspection frequency is once every year, four types of gasoline vehicles are all inspected, and idling test is used in the annual inspection. Therefore, these inputs are much different from the U.S.A. default values.

Temperature and Speed

Ambient temperature is used to compute emission factors for a short time period, such as that used for hourly analysis in the air quality model. For emission factors of longer time periods at assessment year, the minimum and maximum daily temperatures of January and July are used.

The speed is the average running speed, including the combination of idling, acceleration, deceleration and cruising mode. The speed can be measured on road or modeled by traffic assignment software.

Vehicle Miles Traveled Mix by Vehicle Type

The Vehicle Miles Traveled (VMT) mix specifies the fraction of total road VMT that is accumulated by each vehicle type. In MOBILE5 VMT mix is used only to compute the composite emission factor of a vehicular fleet, a city or an area on the basis of the emission factors of each type of vehicle.

In this paper, we suggest to compute the VMT mix of a city or an area with the following equation.

$$VMIX_j = \frac{\sum_{i=1}^{N_j} \frac{R_{ij}}{\sum_{i=1}^{N_j} \sum_{j=1}^8 R_{ij}} \cdot L_{ij}}{\sum_{i=1}^{N_j} \sum_{j=1}^8 \frac{R_{ij}}{\sum_{i=1}^{N_j} \sum_{j=1}^8 R_{ij}} \cdot L_{ij}} \quad (2)$$

where $VMIX_j$ is the VMT mix of j th type of motor vehicle and L_{ij} is annually mileage accumulation rates of j th type of vehicles at i th vehicle age. R_{ij} and N_j have been described in Equation (1).

Idling Emission Factors

The idle emission factors of vehicles stopped at intersections are necessary for pollution analysis of Urban Transport Planning. In MOBILE5 the idle emission factors by vehicle type are considered as product of 2.5 miles per hour and computed emission factors at speed of 2.5 miles per hour, which may be less than the real idle emission factors.

DERIVATION OF EMISSION FACTORS FOR NANJING CITY

After proposing corrections to the key parameters for running MOBILE5 to adapt specific situations of Chinese cities, we step further to accomplish the following: a) collect necessary data specific for Nanjing; b) generate inputs for MOBILE5; c) compute the emission factors; and d) do field experiment to verify the emission factors for Nanjing City.

Data collection

In June 1999, data were collected for all annually inspected motor vehicles from the Department of Motor Vehicle Management of Nanjing City. Data collected included vehicle type, registration date, mileage accumulation, and the tested idle emissions of CO and HC.

For all vehicle types, regression analysis was conducted to relate the mileage accumulation, as dependent variable, with the vehicle age, as independent variable. The logarithm regression equations were found to result in the best fitting, which satisfy the statistical F test with a statistical significance of 99%. The resulting regression equations are given in the following (3)-(6) and the details are provided in TABLE 3.

$$\text{Passenger car:} \quad MA_1 = 6.9638 * \ln(x) + 4.6754 \quad (3)$$

$$\text{Mini-vehicle, jeep, middle vehicle:} \quad MA_2 = 5.7203 * \ln(x) + 1.2004 \quad (4)$$

$$\text{Heavy duty gasoline/diesel vehicle:} \quad MA_3 = 4.8109 * \ln(x) + 1.9302 \quad (5)$$

$$\text{Motorcycle:} \quad MA_4 = 1.0417 * \ln(x) + 0.5814 \quad (6)$$

where x is the vehicle age and MA_j is the mileage accumulation for vehicle type j .

The regression data for passenger car and motorcycle are shown respectively in Figures 1 and 2. The annually mileage accumulation rates for each vehicle type is computed by the following equation and the results are illustrated in TABLE 4.

$$AMCR_{ij} = \begin{cases} MA_j(1) \\ MA_j(i+1) - MA_j(i) \end{cases} \quad 1 \leq i \leq 12, 1 \leq j \leq 4 \quad (7)$$

where i is the vehicle age and j is the vehicle type.

The registration distributions of motor vehicles computed using Equation (1) with data collected from Nanjing Traffic Management Bureau are provided in TABLE 5.

The input values of MOBILE5 parameters for the annual inspection program in Nanjing are described as follows. Annual inspection program started in 1990. The failure ratio of vehicles' first test is 15 percent. The earliest registration year of inspected vehicles was 1985. The waiver rate is zero and the compliance rate is 98 percent. The vehicles are inspected once

every year at inspection station. Four types of gasoline vehicle are all inspected. The idle test is used.

The temperature data from Nanjing National Weather Station are illustrated in TABLE 6.

The assessment year was 1999 and the BERs are given in TABLE 2. The deterioration rates are taken as the values related to the Basic Emission Rates of FTP-75 cycle. Mini-vehicle and jeep are equivalent as Light Duty Gasoline Trucks 1 and middle vehicle is Light Duty Gasoline Trucks 2.

Emission Factors for Nanjing City

By inputting the collected data and necessary parameters, the emission factors were computed using MOBILE5 and the results are illustrated in TABLE 7. The computed idle emission factors are given in TABLE 8.

The changes of HC, CO and NO_x emission factors in TABLE 7 related to the average speed of motor vehicles are shown as Figure 3, Figure 4 and Figure 5. From these figures, we have the following observations:

1. The HC emission factors for all vehicle types decrease with the increase of average speed. The HC emission factors of motorcycle change little when the average speed is greater than 40 km/h.
2. The CO emission factors for all vehicle types decrease with the increase of average speed. But the values of heavy duty gasoline vehicles increase when the average speed is greater than 70 km/h. The CO emission factors of heavy duty gasoline vehicles are much greater than those of other vehicle types.
3. The NO_x emission factors of heavy duty diesel vehicles decrease firstly with the increase of average speed, but increase after the speed is greater than 55 km/h. The NO_x emission factors of heavy duty gasoline vehicles increase with the increase of average speed.
4. The NO_x emission factors of motorcycle are the least. The values of passenger car are greater and the values of mini-vehicle are even greater. The NO_x emission factors of middle vehicle, jeep, mini-vehicle and passenger car have little changes when the average speed increases from 20 km/h to 70 km/h.

Validation of Emission Factors for Nanjing City

In July 1999, we did the field experiment on traffic parameters and pollutants' concentrations at selected road and signalized intersection in Nanjing City (24). Traffic parameters, pollutant concentrations, meteorological parameters and topography of the signalized intersections were measured by professional monitor institutions. Traffic volumes and vehicle speeds by vehicle type were measured with the automatic traffic counting equipment. Traffic volume, signal cycle length, vehicle arrival rate, saturation flow rate and stopped delay were observed. Nine sample locations were chosen and the concentrations of CO, NO_x and O₃ were measured with ecolyzers. Wind speed, wind direction, temperature, cloud amount, cloud category, atmosphere pressure and solar radiation were also measured.

CAL3QHC (25) is the model developed by U.S. Environmental Protection Agency (EPA) to compute CO concentrations at intersections. CALINE4 by Benson (26) is a dispersion model to compute CO and NO_x concentrations near roads, which is widely used. Based on CAL3QHC and CALINE4 we developed a model CAL4Q to simulate the CO and NO_x concentrations at signalized intersections (27). The emission factors listed in TABLE 7 and TABLE 8 were input

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into CAL4Q to compute the concentrations of CO and NO_x at nine locations measured. The computed concentrations matched well with the measured concentrations.

The scatter plot of the computed and measured concentrations of CO is shown in Figure 6. A linear least-square regression analysis of the computed and measured concentrations of CO resulted in the slope 1.05 and the correlation coefficient 0.86 while the intercept was enforced to be zero. The percentage ratio is 91% when the ratio of computed concentrations to the measured is between 0.5 and 2.

For NO_x concentrations the slope and correlation coefficient of the regression analysis are respectively 0.77 and 0.65. The percentage ratio is 79.5%.

Comparison with Results of Previous Work

Compared with He's results of emission factors in Beijing of China (22), the derived CO emission factors in Nanjing for passenger car are 25% higher. This is due to the stricter emission standard for new passenger cars in Beijing than in Nanjing. For the other types of vehicles, differences between the values of emission factors in these two cities are within 15%.

Emission factors for high-class highways are recommended in the Specification for Environmental Impact Assessment on Highway of China (28). The recommended emission factors were tested in tunnels and from dynamometer using cruising vehicle speed. For CO and NO_x emission factors of passenger car from speed of 50km/h, which is the minimum speed in the Specification, to 80 km/h, the recommended values in the Specification are about 10% lower. For heavy duty vehicles in the Specification the emission factors are between the values for heavy duty gasoline vehicle and for heavy duty diesel vehicle.

CONCLUSIONS

China does not have an emission factor model that has been developed based on the emission tests on its own vehicle and traffic conditions. Before China develops its own emission factor models, the use of MOBILE with certain corrections based on the unique vehicle and traffic scenarios seems unavoidable. In order to generate emission factors for estimating pollution inventory and conducting Environmental Impact Assessment on the scenarios of Urban Transport Planning, we used MOBILE5 to generate the emission factors for Nanjing City by correcting the key parameters, such as BERs, Annual Mileage Accumulation Rates, registration distribution, I/M program, temperature and speed, and Vehicle Miles Traveled mix. The derived emission factors have been proved to be valid by our field experiment of traffic parameters and emission concentrations at the signalized intersections in Nanjing.

The derived emission factors can be used in Nanjing to estimate the emission inventory of road traffic and be input into the dispersion model to compute emission concentrations for assessment of environmental impact on Urban Transport Planning scenarios. These emission factors for Nanjing can also be used for other nearby cities, such as Zhenjiang, which has similar vehicle and traffic conditions. The methods used in this paper in collecting the data, and equations used to compute the corrections to MOBILE5 input parameters are also adaptive to other Chinese cities for derivation of emission factors.

Analyzing the emission factors for Nanjing we found that Heavy Duty Vehicle emits much more pollution, and the emission will be less if the average speed is greater than 30 km/h. So the emissions will decrease significantly by improving traffic flows intended to reduce congestions and increase the average speed.

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TABLE 1 Comparison of Vehicle Types

Classification	Vehicle types						
The tested vehicle types	Passenger car	Mini-vehicle	Jeep	Middle vehicle	Heavy duty gasoline vehicle	Heavy duty diesel vehicle	Motor cycle
Chinese National Emission Test Standard	Light duty vehicle				Heavy duty vehicle		Motor cycle
MOBILE5	Light duty gasoline vehicle	Light duty gasoline truck 1	Light duty gasoline truck 2		Heavy duty gasoline vehicle	Heavy duty diesel vehicle	Motor cycle
	Light duty diesel vehicle	Light duty diesel truck					

TABLE 2 The Transferred Basic Emission Rates of Tested Vehicles from Chinese National Standard Driving Cycle to FTP-75 Cycle

Vehicle types	The transferred Basic Emission Rates		
	CO	HC	NO _x
Passenger car (g/km)	28.833	2.332	1.267
Mini-vehicle (g/km)	16.964	3.819	2.047
jeep (g/km)	22.445	4.167	3.143
Middle vehicle (g/km)	33.082	6.378	4.423
Heavy duty gasoline vehicle (g/kWh)	164.60	29.57	17.29
Motorcycle (g/km)	8.510	1.793	0.087

TABLE 3 Regression Equations of Mileage Accumulation by Age and Vehicle Type of Motor Vehicles in Nanjing City

	Passenger car	Mini-vehicle, jeep, middle vehicle	Heavy duty gasoline vehicle, heavy duty diesel vehicle	Motorcycle
Regression equations	$y = 6.9638\ln(x) + 4.6754$	$y = 5.7203\ln(x) + 1.2004$	$y = 4.8109\ln(x) + 1.9302$	$y = 1.0417\ln(x) + 0.5814$
Correlation coefficient	0.524	0.532	0.582	0.575
Statistical F	28.1	21.75	31.7	54.3
Sampling numbers	76	57	64	112
Critical value of F with Confidence Level of 99%	$F(0.01, 74) = 7.0$	$F(0.01, 55) = 7.12$	$F(0.01, 62) = 7.08$	$F(0.01, 110) = 6.89$

**TABLE 4 Annual Mileage Accumulation Rates of Motor Vehicles in Nanjing City
(100 thousand mile)**

Vehicle age	Passenger car	Mini-vehicle, jeep, middle vehicle	Heavy duty gasoline vehicle, heavy duty diesel vehicle	Motorcycle
1	0.29052	0.07459	0.11994	0.03613
2	0.29994	0.24638	0.20721	0.04487
3	0.17545	0.14412	0.12121	0.02625
4	0.12449	0.10226	0.08600	0.01862
5	0.09656	0.07932	0.06671	0.01444
6	0.07889	0.06481	0.05450	0.01180
7	0.06670	0.05479	0.04608	0.00998
8	0.05778	0.04746	0.03992	0.00864
9	0.05097	0.04187	0.03521	0.00762
10	0.04559	0.03745	0.03150	0.00682
11	0.04124	0.03388	0.02849	0.00617
12	0.03765	0.03093	0.02601	0.00563

TABLE 5 Registration Distribution of Motor Vehicles in Nanjing City

Vehicle age	Passenger car	Mini-vehicle, jeep, middle vehicle	Heavy duty gasoline vehicle, heavy duty diesel vehicle	Motorcycle
1	0.094	0.132	0.032	0.036
2	0.184	0.189	0.317	0.282
3	0.105	0.113	0.206	0.164
4	0.158	0.094	0.19	0.127
5	0.105	0.094	0.111	0.136
6	0.105	0.151	0.079	0.082
7	0.132	0.075	0.016	0.091
8	0.013	0.057	0.016	0.009
9	0.013	0.019	0.001	0.036
10	0.013	0.019	0.001	0.027
11	0.026	0.019	0.001	0.009
12	0.026	0.038	0.03	0.001

TABLE 6 Temperature Data of Nanjing City

	January, 1999	July, 1999
Average daily temperature(°C)	2.3	29.5
Minimum daily temperature (°C)	-0.8	26.2
Maximum daily temperature (°C)	6.4	33.4

TABLE 7 Emission Factors of Motor Vehicles in Nanjing City (g/(veh*km))

Average speed (km/h)	Pollutants	Passenger car	Mini-vehicle	Middle vehicle	Heavy duty gasoline vehicle	Heavy duty diesel vehicle	Motor-cycle	Jeep
10	HC	12.37	16.89	26.21	23.57	11.70	9.03	18.14
	CO	122.93	71.30	118.65	357.79	45.24	41.29	87.15
	NOx	2.10	3.18	5.33	4.06	63.22	0.09	4.82
20	HC	7.58	10.18	15.80	14.28	8.75	5.69	10.93
	CO	76.97	45.79	76.20	221.23	29.11	19.48	55.97
	NOx	1.88	2.86	4.79	4.32	50.95	0.08	4.33
30	HC	5.92	7.91	12.30	9.24	6.77	4.65	8.50
	CO	61.65	37.28	62.05	148.86	20.10	12.89	45.57
	NOx	1.81	2.76	4.61	4.57	43.37	0.09	4.17
40	HC	4.57	6.25	9.71	6.39	5.40	4.13	6.71
	CO	44.72	27.78	46.22	108.53	14.81	9.62	33.95
	NOx	1.86	2.74	4.59	4.83	38.93	0.10	4.15
50	HC	3.72	5.22	8.10	4.77	4.48	3.78	5.60
	CO	33.56	21.46	35.71	86.61	11.77	7.49	26.23
	NOx	1.90	2.76	4.61	5.08	36.99	0.12	4.17
60	HC	3.15	4.53	7.03	3.78	3.84	3.52	4.87
	CO	26.10	17.25	28.69	75.21	10.04	6.05	21.08
	NOx	1.93	2.76	4.62	5.33	37.12	0.12	4.18
70	HC	2.74	4.04	6.26	3.18	3.40	3.38	4.34
	CO	20.77	14.23	23.67	71.07	9.17	5.18	17.39
	NOx	1.95	2.77	4.63	5.58	39.34	0.13	4.19
80	HC	2.50	3.75	5.82	2.84	3.12	3.33	4.03
	CO	17.76	12.53	20.84	73.10	9.00	4.80	15.31
	NOx	2.05	2.95	4.93	5.83	44.04	0.14	4.46
90	HC	2.56	3.84	5.95	2.70	2.96	3.43	4.12
	CO	19.23	13.45	22.36	81.81	9.46	5.84	16.43
	NOx	2.40	3.58	6.00	6.09	52.05	0.16	5.42

TABLE 8 Idle Emission Factors of Motor Vehicles in Nanjing City (g/(veh*hour))

Pollutants	Passenger car	Mini-vehicle	Middle vehicle	Heavy duty gasoline vehicle	Heavy duty diesel vehicle	Motor-cycle	Jeep
HC	60.48	87.95	138.57	78.58	35.36	34.81	94.73
CO	647.38	367.09	610.85	1240.68	152.09	222.14	448.68
NO _x	6.80	10.34	17.30	9.78	184.49	0.25	15.65

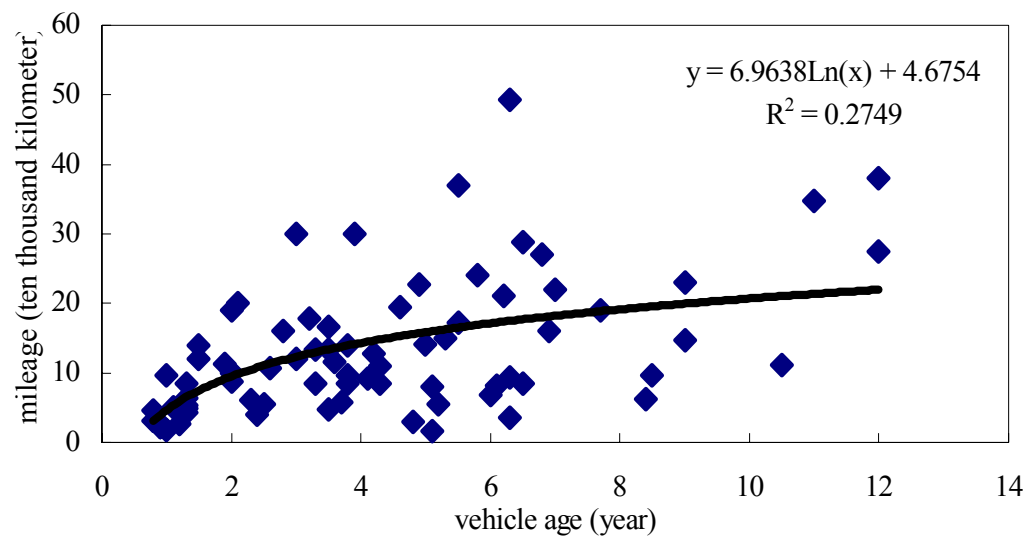


FIGURE 1 Data regression analysis of mileage accumulation with vehicle age for passenger car.

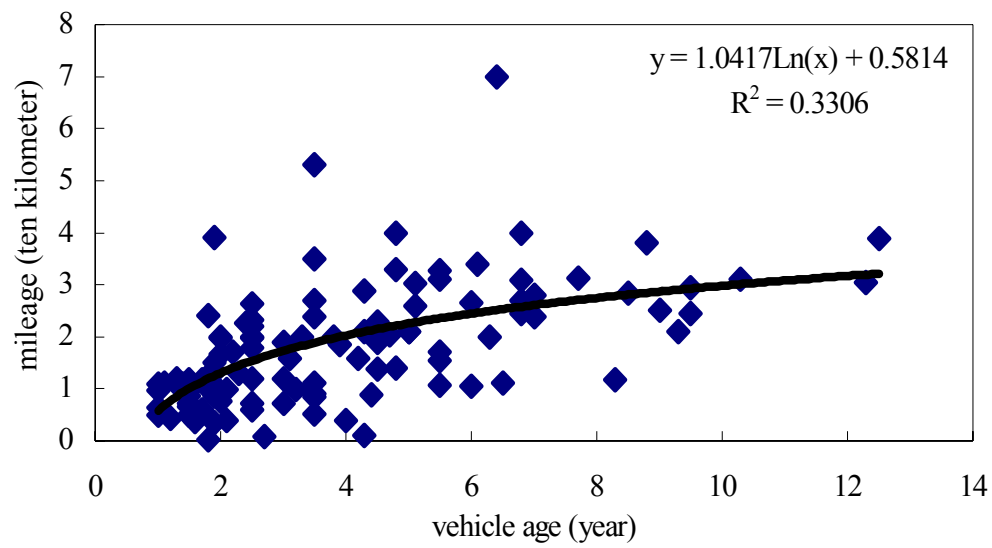


FIGURE 2 Data regression analysis of mileage accumulation with vehicle age for motorcycle.

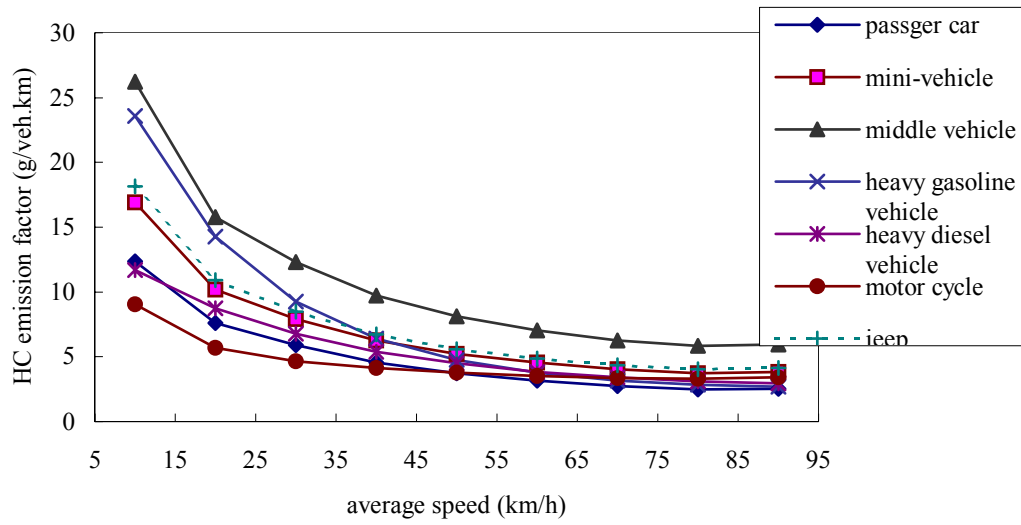


FIGURE 3 The relation of computed HC emission factor with average speed.

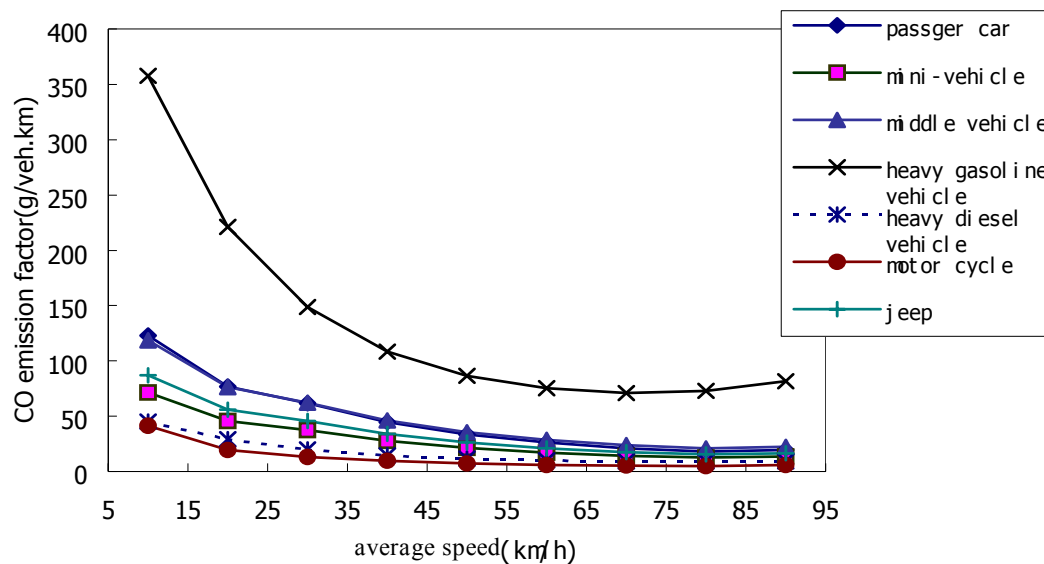


FIGURE 4 The relation of computed CO emission factor with average speed.

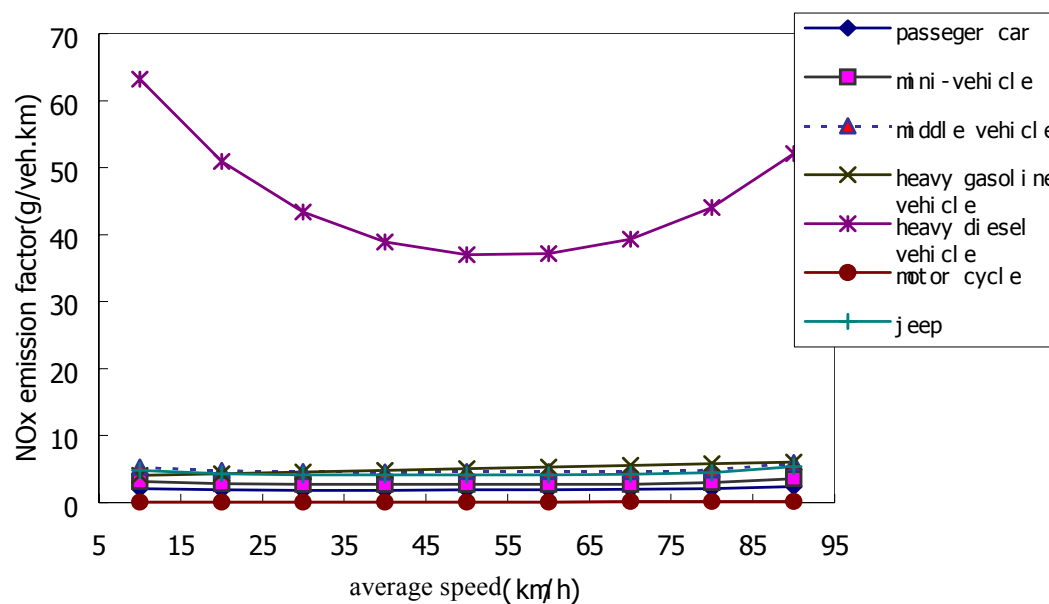


FIGURE 5 The relation of computed NO_x emission factor with average speed.

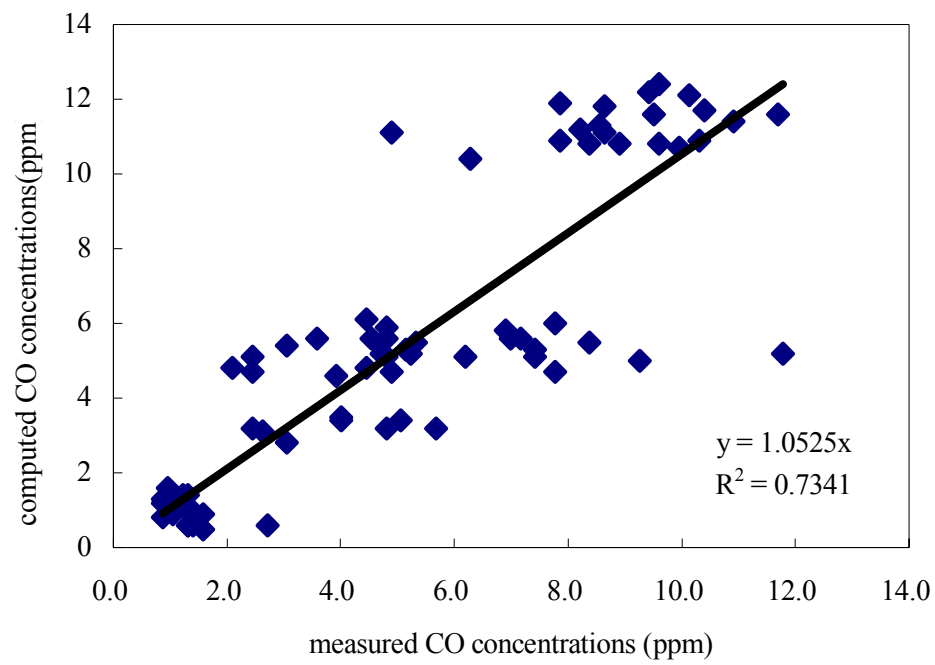


FIGURE 6 Regression analysis of measured and computed CO concentrations near the signalized intersection.

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